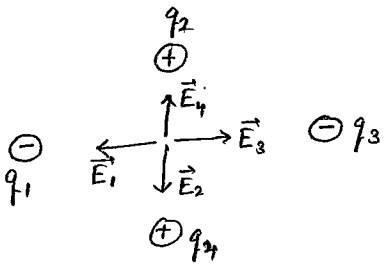
(Solution to Final Exam, PHYS-203B, Fall 2015)

Prob. 1

$$\vec{E}_1 = -\hat{i}\,\frac{k|q_1|}{L^2} \qquad \vec{E}_2 = -\hat{j}\,\frac{k|q_2|}{L^2}$$

$$\vec{E}_3 = +\hat{i}\,\frac{k|q_3|}{L^2} \qquad \vec{E}_4 = +\hat{j}\,\frac{k|q_4|}{L^2}$$



$$\vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 = 0$$

(because $|q_1| = |q_3|$ and $|q_2| = |q_4|$.)

Prob. 2

$$a = \frac{qE}{m} = \frac{1.6\times10^{-19}\times4.0\times10^{3}}{1.67\times10^{-27}} = 3.8\times10^{11}\ \frac{m}{s^2}$$

$$x = \frac{1}{2}at^2 = \frac{1}{2}\times3.8\times10^{11}\ \frac{m}{s^2}\ (1.0\times10^{-9}\,s)^2 = 1.9\times10^{-7}\ m.$$

Prob. 3

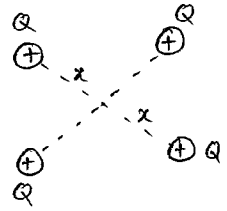
$$V = \frac{kQ}{x} + \frac{kQ}{x} + \frac{kQ}{x} + \frac{kQ}{x}$$

$$= 4\sqrt{2}\,\frac{kQ}{L}$$

$$= 4\sqrt{2}\,\frac{9.0\times10^{9}\times1.0\times10^{-6}}{5.0\times10^{-2}}$$

$$= 1.02\times10^{6}\ \text{Volt}$$

$$x = \sqrt{2}\,\frac{L}{2} = \frac{L}{\sqrt{2}}.$$



Prob. 4

(a) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{100} + \frac{1}{200} = \frac{3}{200}$ $\Rightarrow R_{eq} = \frac{200}{3} = 66.7\ \Omega$

(b) $V_1 = V_2 = 10.0\ V$

(c) $I_1 = \frac{V_1}{R_1} = \frac{10.0}{100} = 0.100\ A$

$I_2 = \frac{V_2}{R_2} = \frac{10.00}{200} = 0.050\ A$

(d) $P_1 = I_1 V_1 = 1.00\ W$ $\qquad P_2 = I_2 V_2 = 0.50\ W$

Prob. 5

(a) $|\vec{F}_1| = I L_1 B \sin 90$

$= 2.0\,A \times 4.0\times10^{-2}\,m \times 2.0\,T \times 1$

$= 0.16\,N$

direction of F_1 : $+\hat{j}$

$\vec{F}_1 = +\hat{j}\ 0.16\,N$

(b) $|\vec{F}_2| = I L_2 B \sin 90$

$= 2.0\,A \times 3.0\times10^{-2}\,m \times 2.0\,T \times 1$

$= 0.12\,N$

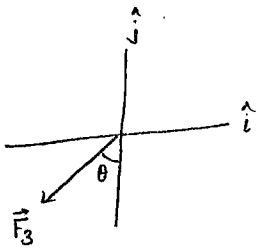
direction of F_2 : $+\hat{i}$

$\vec{F}_2 = +\hat{i}\ 0.12\,N$

(c) $|\vec{F}_3| = I L_3 B \sin 90$

$= 2.0\,A \times \sqrt{3.0^2 + 4.0^2} \times 10^{-2}\,m \times 2.0\,T$

$= 0.20\,N$



$\theta = \tan^{-1}\left(\frac{3.0}{4.0}\right)$

$= 36.9$

$\vec{F}_3 = -F_3 \sin\theta\ \hat{i} - F_3 \cos\theta\ \hat{j}$

$= -0.20 \sin 36.9\ \hat{i} - 0.20 \cos 36.9\ \hat{j}$

$= -0.12\,N\ \hat{i} - 0.16\,N\ \hat{j}$

(d) $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = \left(+\hat{j}\ 0.16\,N\right) + \left(\hat{i}\ 0.12\,N\right) + \left(-0.12\,N\ \hat{i} - 0.16\,N\ \hat{j}\right)$

$= 0.$

Prob. 6

$\vec{B} = -\hat{z}\ \frac{\mu_0 I}{2\pi a}\ \frac{1}{2} \quad -\hat{z}\ \frac{\mu_0 I}{2a}\ \frac{1}{4} \quad -\hat{z}\ \frac{\mu_0 I}{2\pi a}\ \frac{1}{2}$

$= -\hat{z}\ \frac{\mu_0 I}{4a}\left(\frac{2}{\pi} + \frac{1}{2}\right)$

$|\vec{B}| = \frac{4\pi\times10^{-7}\ 1.0}{4\times10\times10^{-2}}\left(\frac{2}{\pi} + \frac{1}{2}\right) = 3.6\times10^{-6}\ T$

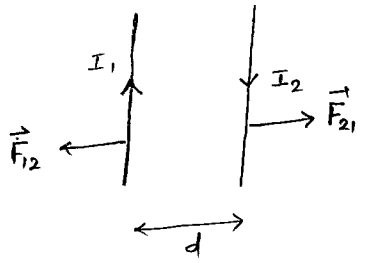
direction : into the page.

Prob. 7

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d} = \frac{4\pi \times 10^{-7} \times 1.0 \times 2.0}{2\pi \times 20.0 \times 10^{-2}}$$

$$= 2.0 \times 10^{-6} \ \frac{N}{m}$$

direction: they repel each oth



Prob. 8

(a) increasing

(b) anti clockwise.

(c) $I = \frac{V_{eff}}{R} = \frac{B l v}{R} = \frac{1.0\,T \times 5.0 \times 10^{-2}\,m \times 2.0\,\frac{m}{s}}{0.50\,\Omega} = 0.20\ A$

Prob. 9

(a) $I_A = \frac{I_0}{2} = 0.5\ I_0$

(b) $I_B = I_A \cos^2(45-0) = \frac{1}{2} I_A = \frac{1}{4} I_0 = 0.25\ I_0$

(c) $I_C = I_B \cos^2(90-45) = \frac{1}{2} I_B = \frac{1}{8} I_0 = 0.125\ I_0$

(d) $I_C' = I_A \cos^2(90-0) = 0.$

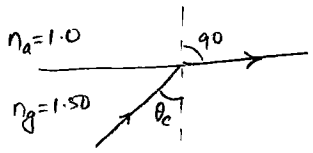
Prob. 10

$$n_g \sin\theta_c = n_a \underbrace{\sin 90}_{=1}$$

$$\theta_c = \sin^{-1}\left(\frac{n_a}{n_g}\right)$$

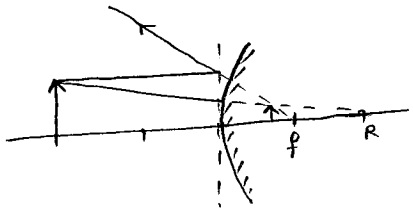
$$= \sin^{-1}\left(\frac{1.0}{1.5}\right)$$

$$= 41.8^\circ$$



Prob. 11

(f)



(a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{1}{20} + \frac{1}{d_i} = \frac{1}{-10}$

$\frac{1}{d_i} = -\frac{1}{10} - \frac{1}{20} = -\frac{3}{20} \Rightarrow d_i = -6.67\,cm$

(b) $m = -\frac{d_i}{d_o} = -\frac{(-6.67cm)}{20.0\,cm} = 0.334$

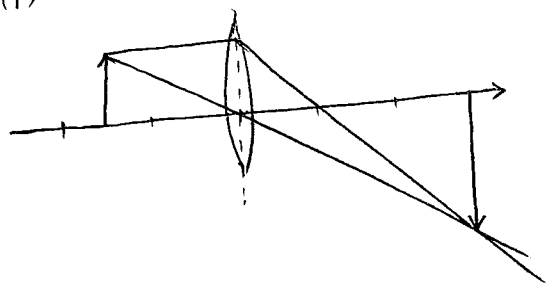
(c) virtual

(d) upright

(e) $h_i = m\,h_o = 0.334 \times 1.0cm = 0.334\,cm$

Prob. 12

(f)



(a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$\frac{1}{15} + \frac{1}{d_i} = \frac{1}{10}$

$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{15} = \frac{1}{30} \Rightarrow d_i = 30.0\,cm$

(b) $m = -\frac{d_i}{d_o} = -\frac{30.0cm}{15.0\,cm} = -2.00$

(c) real

(d) inverted

(e) $h_i = m\,h_o = -2.00 \times 1.00\,cm = -2.00\,cm$